Diffractive physics and the Odderon

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$$F_s = is\, f(ln\tilde{s}), \qquad F_a = -s\, g(ln\tilde{s}) \tag{2}$$

where $f(z)$ and $g(z)$ are real functions of $z = lns$ and $\tilde{s} = s\, e^{-i\pi/2}$.
From the FROISSART-MARTIN theorem on total cross sections [5] we have, asymptotically

$$\{|f|, |g|\} < const\ ln^2 s. \tag{3}$$

We now make the following assumptions
i) *A C-odd asymptotic term exists;*
ii) *f and g are smooth non oscillating functions (bounded by (3)).*
In this case, for any $s > s_1$, (where s_1 is some arbitrary energy) we can write

$$f(z) \approx f(x) - i\pi/2 f'(x), \qquad g(z) \approx g(x) - i\pi/2 g'(x) \tag{4}$$

where $f(x), g(x), f'(x)$ and $g'(x)$ are real functions of $x = lns$ and we have defined $f'(x) = df/dx|_{z=x}$ and $g'(x) = dg/dx|_{z=x}$.
We then have, identically,

$$\bar{\sigma} \approx 4\pi(f + \pi/2g'), \qquad \sigma \approx 4\pi(f - \pi/2g') \tag{5}$$

and

$$\bar{\rho} \approx \frac{(\pi/2)f' - g}{f + (\pi/2)g']}, \qquad \rho \approx \frac{(\pi/2)f' + g}{f - (\pi/2)g']} \tag{6}.$$

where $\bar{\sigma}$, σ, $\bar{\rho}$ and ρ are the $\bar{p}p$ and pp total cross sections and the ratios of the real to the imaginary parts of the forward scattering amplitude respectively. With these quantities, we can construct the following combinations

$$RS(\sigma, \rho) \equiv \frac{(\bar{\rho} + \rho)}{(\bar{\sigma} + \sigma)} \approx \frac{2\pi^2}{\bar{\sigma}\sigma}[f' + gg'/f] \tag{7}$$

$$RD(\sigma, \rho) \equiv \frac{(\bar{\rho} - \rho)}{(\bar{\sigma} - \sigma)} \approx -\frac{\bar{\sigma} + \sigma}{\pi\bar{\sigma}\sigma}\frac{g}{g'}[1 + \pi^2/4\,\frac{g'}{g}\frac{f'}{f}] \tag{8}$$

III. A THEOREM

With the previous notation, we have now the following *theorem*: **irrespective of whether f and g grow, tend to constants or decrease**

$$f'/f \quad \text{and} \quad g'/g = O(K/lns) \tag{9}$$

where K is some constant (a somewhat more general theorem has been subsequently proved in [5]).

IV. CONSEQUENCES

As a consequence of the above theorem, we have from eq. (8)

$$RD(\sigma, \rho) \approx -\frac{\bar{\sigma} + \sigma}{\pi\bar{\sigma}\sigma}\frac{g}{g'} \approx -\frac{\bar{\sigma} + \sigma}{\pi\bar{\sigma}\sigma}\frac{ln\, s}{K}. \tag{10}$$

We can now consider the following options:
i) **g grows** implying an *important asymptotic role of the Odderon at t=0.* In this case, $g'/g > 0$ (and $K > 0$) which implies

$$RD(\rho, \sigma) < O. \tag{11a}$$

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Summary *We briefly discuss how the C-negative trajectory known as the Odderon could be detected from purely diffractive physics.*

I. PRELIMINARIES

Diffractive physics is known to be dominated by vacuum exchange or, in the Regge-poles language, by the exchange of the *Pomeron* (*i.e.* of the trajectory with quantum numbers of the vacuum with C-positive).

More exactly, we know that essentially all elastic data can be well reproduced in the small t-domain with just 5 Regge trajectories, the Pomeron, the ρ the f_2, the A_2 and the ω as they are nicknamed (see [1]. Actually, due to the so-called exchange degeneracy, we have a remarkable economy of parameters since all these trajectories are, essentially, degenerate (see. Fig. 1). By contrast, the Pomeron trajectory is very much different: much more flat and we are not even sure that any particle is experimentally known on such a trajectory. The latter is supposed to interpolate C-positive two-gluon bound states which we call *glueballs* (as Fig. 2 shows, however, one such state may have already been established).

While it has been known for a long time that nothing prevents a C-negative trajectory (with all other quantum numbers of the Pomeron) to be equally present [2], no firm evidence in favor of this object (called *Odderon*) has yet been found. If, however, one wants to reproduce also high t-data, such a contribution appears quite necessary [3]. Fig. 3 shows an example of how models combining such a negative C contribution with the full-fledged machinery necessary in the small-t domain can reproduce all high energy pp and $\bar{p}p$ data simultaneously. The interest in these models is manyfold but notice especially the prediction of secondary maxima and minima at increasing energies and momentum transfer which is going to be matter of investigation at LHC).

The question which we wish to address here and which remains entirely open, however, is whether there can be any way to detect possible C-negative contributions not in the large-t but in the small-t region, *i.e.* from diffractive physics alone.

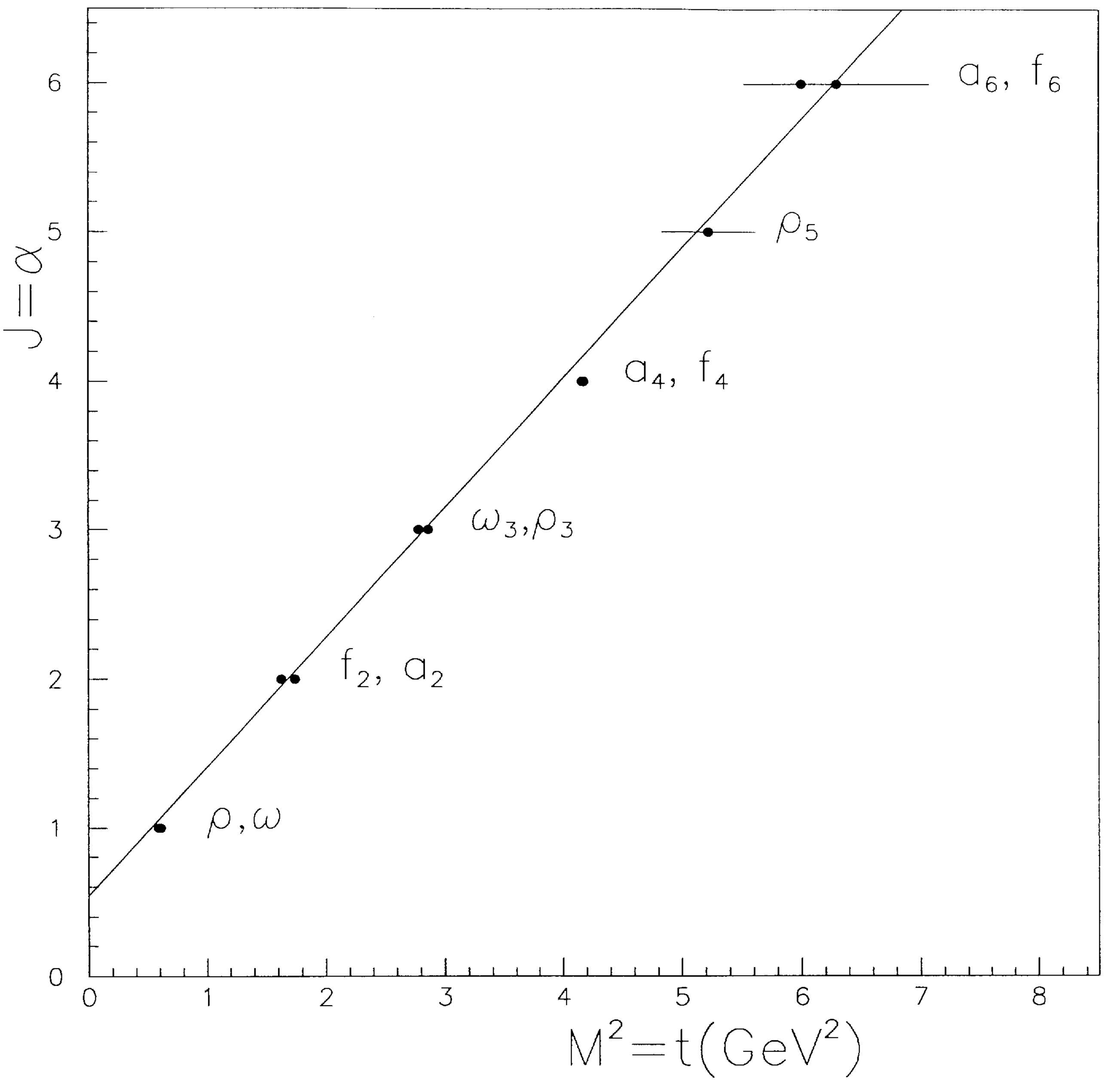
Such a possibility, curiously enough, has not been addressed until rather recently and, even more curiously, can be rather easily answered in the positive [4]. More precisely, in [4], the following somewhat unexpected result has been proved: ***an asymptotic C-negative amplitude, (if of any relevance) could be detected from purely forward data provided very precise t=0 data are simultaneously available for both pp and $\bar{p}p$ reactions.***

II. DEFINITIONS

Let F and $\bar{F}$ be the proton-proton and the proton-antiproton amplitudes respectively (the same notation will be used throughout the rest of this paper). We define the *Symmetric* and the *Antisymmetric* amplitudes as

$$F_s = (1/2)[\bar{F} + F], \qquad F_a = (1/2)[\bar{F} - F]. \tag{1}$$

From analyticity (forward dispersion relations) and s-u crossing, we can write



$J = \alpha$
$M^2 = t(\mathrm{GeV}^2)$
ρ, ω
$f_2,\ a_2$
ω_3, ρ_3
$a_4,\ f_4$
ρ_5
$a_6,\ f_6$
0
1
2
3
4
5
6
7
8

This is, incidentally, what high energy fits [3] to all proton-proton and proton-antiproton data seem to suggest.

ii) g **tends to zero** implying a *negligible asymptotic role of the Odderon at t=0.* In this case $g'/g < 0$ (and $K < 0$) which implies

$$RD(\rho, \sigma) > 0. \tag{11b}$$

iii) g **tends to a constant**. In this case g'/g (and, accordingly, K) can have either sign so that $RD(\rho, \sigma)$ does not provide any conclusive information and one would have to resort to other combinations of σ's and ρ's to discriminate. Specifically, in this case

$$(\bar{\sigma}' - \sigma')(\bar{\rho} - \rho) > 0 \tag{12}$$

where $\sigma' \equiv \frac{d\sigma}{dt}|_{t=0}$.

V. CONCLUSIONS

We have shown that the sign of $RD(\rho, \sigma)$ signals the presence or the absence of an important asymptotic role of the Odderon. At present, an unbiased fit to all data (from the ISR, the S$\bar{p}p$S, FNAL and the Tevatron) would give a positive sign for RD which would be in line with the familiar assumption that the Odderon is not very relevant at $t = 0$. The extrapolation of this result to higher energies, however, is not incompatible with an asymptotically negative sign for RD. Even though the greatest care must be taken when drawing conclusions from an extrapolation, such a result, taken at face value would hint at the possibility of a relevant role of the Odderon at t=0 and at higher energies enhancing the expectations from LHC. In conclusions:

i) *we may be able to confirm (or to dismiss) the importance of the Odderon from purely forward measurements provided both options pp and $\bar{p}p$ are available;*

ii) *diffraction is dominated by the Pomeron (C-even exchange) but a relevant role of the Odderon (C-negative exchange) cannot be excluded from the present data but LHC energies should give a clear cut answer;*

iii) *this conclusions provide further arguments to strongly advocate that LHC be extended to cover also the antiproton option.*

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[3] P. DESGROLARD, M. GIFFON and E. PREDAZZI: Zeit f. Phys. **C63** (1994) 241.

[4] M.GIFFON, E. PREDAZZI and A. P. SAMOKHIN, Phys. Lett. **B 375** (1996) 315.

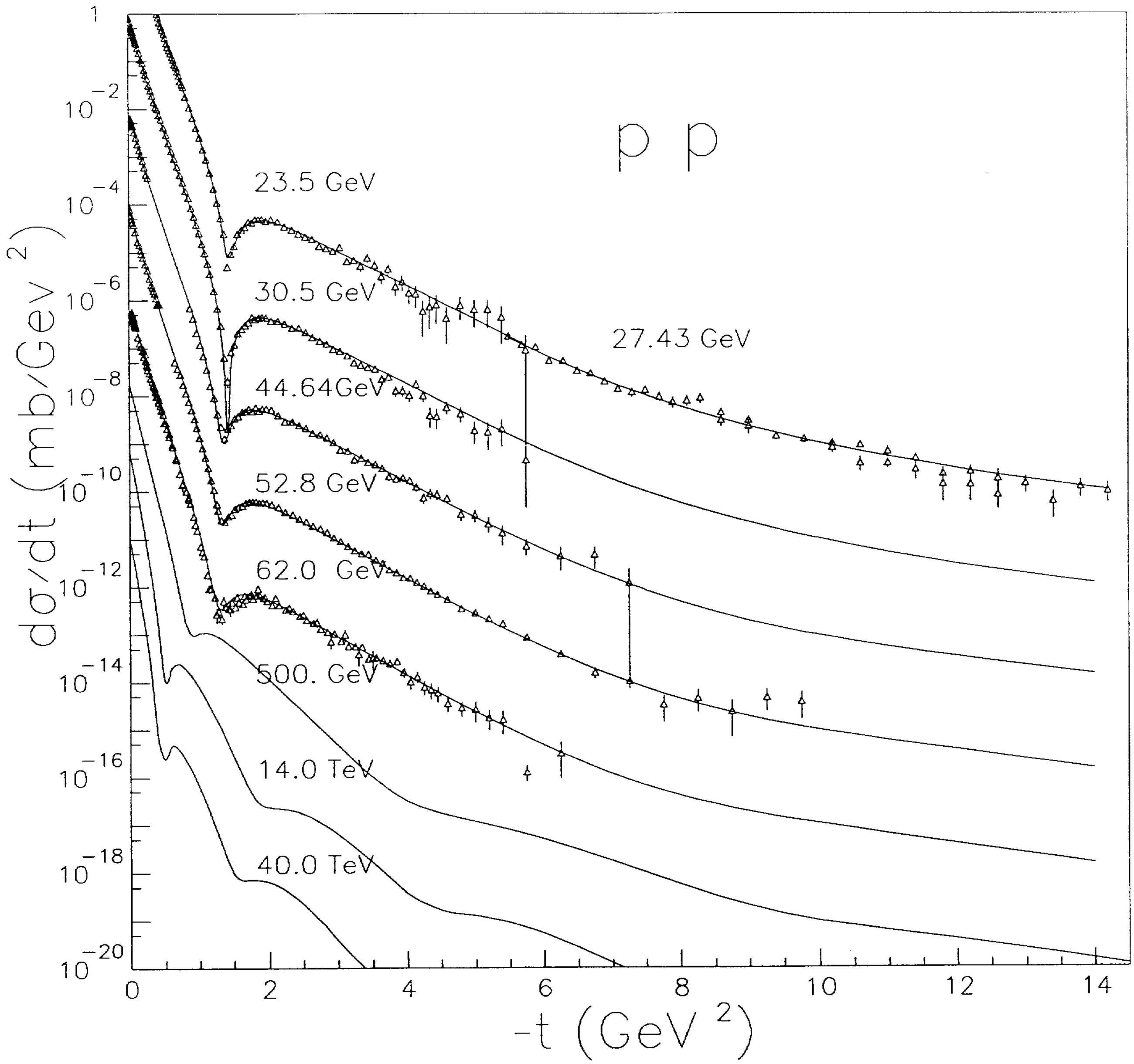
[5] P. GAURON, E. LEADER and B. NICOLESCU, Phys. Lett. **B 397** 126 (1997).

Figure captions.

Fig. 1) Bosonic Regge trajectories as function ot the square masses of the particles interpolated.

Fig. 2) Pomeron Regge trajectory as function ot the square masses.

Fig. 3) *pp* high energy differential cross sections as reproduced by the model of Ref. 3 together with the extrapolation to higher energies .


p p
23.5 GeV
30.5 GeV
27.43 GeV
44.64GeV
52.8 GeV
62.0 GeV
500. GeV
14.0 TeV
40.0 TeV
dσ/dt (mb/GeV 2)
-t (GeV 2)